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SPRUCE BEETLE SURVEY PROCEDURES FOR ASSESSING CURRENT, POTENTIAL AND PAST ENGELMANN SPRUCE MORTALITY IN THE CENTRAL AND SOUTHERN ROCKY MOUNTAINS

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INTRODUCTION

The spruce beetle, *Dendroctonus rufipennis* (Kirby), kills an estimated one-third to one-half million board feet of spruce sawtimber each year throughout North America (Schmid and Beckwith, 1975). Presently, 10.5 billion board feet of merchantable standing or down dead spruce exists in the spruce-fir forests of the western United States; almost all the result of spruce beetle outbreaks (USDA 1977). Most of the beetle-killed standing trees are in groups, but individual dead trees may be scattered throughout the spruce-fir forest.

In the central and southern Rocky Mountains, beetle-killed trees may be detected from the ground or air, but the specific method is influenced by the number, proximity, and degree of fading of the infested treesas well as the accessibility of the forest. Groups of infested trees that are changing color can be aerially detected; this is more efficient in inaccessible areas. Scattered single trees are usually detected from the ground regardless of their fading; rarely from the air when they have turned color.

After infested or dead trees are detected, survey procedures are initiated for evaluating the current, potential, or past spruce mortality. The procedures are different for each type of mortality to be evaluated, so each is discussed separately.

ASSESSING CURRENT AND POTENTIAL TREE MORTALITY

Ground surveys are best for assessing current and potential tree mortality—aerial surveys do not consistently give accurate estimates of the number of infested trees. The ground surveys consist of two types: random examination and systematic survey.

Random Examination

The random examination verifies the spruce beetle as the casual agent of the observed tree mortality, obtains a general visual estimate of brood density and stage of development of the beetles within the currently infested trees, and observes the size (d.b.h.) of the remaining green trees in the infested stand.

The random examination is, as the title implies, a random walk by an entomologist

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through a suspect area with frequent examination of each group of affected trees in the area. Each affected tree is closely observed for spruce beetle activity. Some are examined for brood by chopping out portions of the bark with a hatchet and checking the interior portion of the bark for beetles as well as the outer portion of the wood for blue stain. Other trees are closely examined for evidence of frass and entrance holes to the beetle galleries in the outer bark. Since trees debarked by woodpeckers are a good sign of beetle activity, the observer looks for this condition, and examines such trees. Trees being attacked or attacked just a few months prior will not show this condition so debarked trees also indicate how long ago attacks occurred. The incidence of successfully attacked, pitchouts, and strip attacked trees is noted. The stand density and size of the remaining green trees in relation to the infested trees are briefly recorded.

The examination is best made by a two-man crew sometime during the summer or early fall. It can also be made during the following winter, but substantial accumulations of snow and extreme cold create unsatisfactory working conditions.

The random examination is necessary because not every detection report reveals an infestation or an infestation warranting further action. Frequently, detected infestations consist of only a small number of trees or the trees have been heavily debarked by woodpeckers throughout the first winter so that additional survey information or suppression is not needed. If the examination reveals a serious infestation, a systematic survey of the infested area should be made to provide the data for a biological evaluation

Systematic Survey

The systematic survey strives to estimate the total number of beetle-killed trees with a sampling error of less than 25 percent, determine the infestation trend in the infested trees in order to predict the tree losses for the next year, and determine the susceptibility of the green trees remaining in the stand.

By its basic nature, the systematic survey is a more intensive coverage of the infested area than the random examination. It seeks to gain more detailed data on the number and distribution of infested trees, the brood within them, and the stand structure of the green stand. Since this information may be derived through either one joint survey or three separate surveys, depending on the objectives, the details for each data-gathering process is more easily discussed in separate sections.

Current Tree Mortality

Information on the number of currently infested spruce and uninfested green trees by 1-inch d.b.h. classes is gathered from a combination strip and variable plot cruise. Strip plots are more efficient for infested trees and point sampling for green trees. The data on currently infested trees will indicate the number of trees killed and their distribution by diameter class. Since the survey lines are systematically arranged over the infested area, the tally of infested trees will also indicate somewhat the distribution of the infested trees within the outbreak area. Knowing the number and size of the infested trees, the volume of lumber lost can be computed. The green stand information is used to compute a risk rating for the remaining

stands (see stand susceptibility).

Survey lines are oriented to adequately cover the range of stand conditions in the outbreak area and, if possible, to minimize the physical strenuousness of cross country travel. The survey coverage is varied by changing the distance between the survey lines and what coverage will be used depends on the intensity of tree mortality, the size of the outbreak, and the desired relative sampling error (Knight, et al. 1956). For example, a 2,500-acre infestation with an estimated 10 infested trees per acre should be sampled with a two percent survey to achieve a 25 percent relative sampling error.

Along the survey lines, two-man crews run strip plots end to end with point samples spaced at regular intervals. Each strip plot is 1/2 × 10 chains (33′ × 660′ = 0.5 acre) in size and is established on the line by hand compass and pacing. The compassman walks the survey line, pacing as he goes, and recording the infested trees as noted by the cruiser. The cruiser zigzags across the survey line, observing each spruce over a fixed size, such as 5- or 8-inches d.b.h., within the strip (16.5 ft. on either side of the cruise line).

Within the strip plots, all standing beetle-attacked spruce are recorded by 1-inch class (e.g., 5-inch class = 5.0 – 5.9; 6-inch class = 6.0–6.9). These trees are classified by the year of attack according to the following criteria: 1) new—attacked in the current year, foliage green, phloem whitish appearing like phloem from uninfested tree but with eggs or small larvae in or near the egg galleries; 2) old—attacked at least 1 year prior, foliage green to yellowish-green usually less abundant than on uninfested trees or occasionally absent, phloem deteriorating and brown in color with large larvae, pupae or adults present, bark slightly to heavily woodpeckered, also with emergence holes and perhaps hibernating adults near the ground; 3) snag—attacked at least 2 years prior, no foliage present, phloem dried and brown, bark, if present, with galleries but without live beetles; 4) pitchout—unsuccessfully attacked in the current year, foliage green, bark with masses of pitch and shortened egg galleries filled with resin; 5) strip attack—a partially attacked tree with the attacks concentrated on one side, foliage green, phloem where attacks occured with small larvae or eggs in or near the egg galleries, phloem under the unattacked bark whitish and without egg galleries.

Wind-thrown trees are tallied separately with notes on the presence or absence of beetles and their stage of development. Only that windthrow with green or yellowing foliage is tallied—other older downed trees devoid of needles are ignored.

Point sampling tallies green, live trees on variable-radius plots usually located at the center of each strip plot so the number of variable-radius plots is one per strip plot. Basal area factors (BAF) of 20 or 40 are commonly used, depending on stand density. This does not result in the same percent area survey as the strip plot method because different areas are covered under different stand conditions. A Spiegel-Relaskop most efficiently measures the critical angle

from each plot center on the steep slopes typical of the Rocky Mountains. The number of trees larger than 5 inches d.b.h. on each plot is tallied by species in 1-inch d.b.h. classes.

The strip and variable-radius plots are usually surveyed in the late summer or early fall after the attack period. During that period, stands are still accessible and snow and cold do not hamper fieldwork. If the infestation trend survey is made concurrently with the stand mortality survey, then the combined surveys must be made 1 year later, when the beetles are late larvae to adult stages in order for the sequential sampling plan used in the trend survey to be applicable.

All tree measurement data on both strip and variable plots are recorded on the PEST Field Survey Form to expedite data analyses by the PEST computer program (Acciavatti and Geils, 1977). Stand tables can be generated by PEST and/or green stand structure by host and non-host species as well as by damage classes and standard management size classes. Optional tallies display trees per acre by diameter classes with confidence limits on the estimates for stand totals.

The strip and variable radius plots on coinciding cruise lines have some potential problems which should be mentioned. Since the cruise lines are run with a hand compass, their accuracy is only as good as the compassman. In those cases where the lines deviate significantly from the true line, the location and number of infested trees are recorded incorrectly. Taping and/or back-sighting will reduce errors, but also efficiency. Strip plots are more difficult to cruise with one man than variable radius plots so two-man crews are needed throughout the entire cruise, but work safety is enhanced.

Another problem has been the percent of sample coverage necessary to obtain certain allowable sampling errors. The percent coverage varies with the number of infested trees per acre and the size of the infested area. The strip cruise should be adjusted to provide the needed sample coverage, but this might oversample the green stand using the variable plots. Adjustments in the BAF and point sampling plot locations along the survey lines would reduce any oversampling.

Infestation Trend

Spruce beetle populations in standing trees are evaluated using the sequential sampling plan developed by Knight (1960) to determine the trend of the infestation. The trend is based on the larval densities obtained from 6×6-inch bark samples taken from approximately breast height on infested trees. The larval counts are cumulated and compared to Knight's table which establishes the class limits for the decreasing, static, and increasing infestation trends.

Sample trees are selected irrespective of diameter, degree of debarking by woodpeckers, or proximity to other infested trees;[1] although by scattering the sample trees throughout the infested area, better representation of the infestation is obtained. Samples must be taken in the second August-September period following attack (ca. 1 year after attack). Two samples are taken from each tree—one on the north side and one on the south side. Infestations can be classified on a minimum of 20 sam-

[1] Knight, F. B. 1977. Personal communication. School of Forest Resources, University of Maine, Orono, Maine.

ples (10 trees), although 80 samples (40 trees) may be taken without a decision being made. In the latter case, the infestation is assigned the next higher category.

Sampling must be performed in August-September, so the timing is critical. However, the period is long enough to circumvent any scheduling problems and both access and weather are generally good during these 2 months. If the trend evaluation is made concurrently with a stand mortality survey, then the stand mortality survey must be made during the proper August-September period or the trend evaluation will not be valid.

Knight's plan is restricted to standing infested trees; decisions about the infestation trend of spruce beetle populations in blowdown and logging residuals—two ideal habitats for brood production—must be developed from other criteria. Guidelines indirectly evaluating the infestation potential of populations in logging residuals are available from Schmid (1977), but these are brood production values from four common types of logging residuals and not predictor values. Although specific guidelines are not available for evaluating infestation trends in blowdown, some of the information on logging residuals when combined with experience provides the best estimate of trend presently available.

Stand Susceptability

The potential for an infestation to continue is based largely on the green trees remaining within the outbreak area and the previously discussed estimate of the spruce beetle infestation trend. The green stand data are obtained from the variable radius plots during the systematic ground survey and can be used to rate each stand for potential tree mortality in the rating plan of Schmid and Frye (1976). Stands are categorized into a high, medium, or low potential based on physiographic location, average diameter of live spruce above 10 inches d.b.h., the total stand basal area, and the proportion of spruce in the canopy.

This plan provides a standard method of evaluating spruce-fir stands. The plan requires stand data usually derived from Stage II inventory information. When Stage II data is available, the green tree information does not have to be recorded during the systematic survey. One disadvantage of the plan is that some stands will rate intermediate to the three major categories. This problem is avoided by classfying the stand into the next higher category in the same manner as is done in Knight's sequential sampling plan.

ASSESSING PAST TREE MORTALITY

Knowledge of past tree mortality from spruce beetle outbreaks is often needed to plan salvage logging programs and to evaluate spruce beetle impact on the timber resource. Surveys to estimate past tree mortality may be either ground or aerial photogrammetric, depending on accessibility and size of the infestation as well as survey objectives. Where past outbreaks have occurred in accessible stands less than a section in size (640 acres), ground surveys are the most efficient and economical means of obtaining tree mortality estimates. Estimates of mortality in past outbreaks extending over areas greater than a section or existing in

forests with limited road access are most economically and efficiently gained with aerial photography.

Ground Surveys

Ground surveys are the best way to obtain detailed information on tree size and stand densities in order to evaluate timber losses and stand changes. The ground survey procedures are essentially those described earlier except that only beetle-killed trees are tallied. In light infestations (under 10 trees killed per acre), strip plots are most efficient and provide more reliable estimates of dead trees; whereas in heavier infestations, variable plots provide these advantages. Cruisers must closely examine the dead trees to verify that the spruce beetle was the mortality agent and not such agents as spruce broom rust or dwarf mistletoe. Data collection, recording and analyses, can be done most efficiently with the procedure specified in the PEST computer program.

Aerial Photographic Surveys

The number of dead trees per acre can be estimated with a double sampling technique comprised of three phases: 1) aerial photography; 2) photo interpretation; and 3) ground truth. The ground truth phase subsamples the photo plots and provides a corrected estimate of the actual number of dead trees on these plots.

1. Aerial Photography

The aerial platform consists of a Cessna 206 aircraft equipped with a 70 mm Hasselblad EL/M camera, a 250 mm lens, and a Wratten 12 filter using Kodak 2443 color infrared aerial film. The photo scale should be between 1:3,330 to 1:5,000 feet. Stereo pair or triplet exposures are made at intervals along flight lines. The aerial camera is mounted internally in the aircraft and is secured to the floor with Barry shock mounts. A 4-inch hole in the floor and an 8-inch hole in the aircraft skin accommodate the camera mount. Aircraft drift from 0 to 20 degrees can be corrected with the special mount. The photo flights may be flown any season when the cloud cover is minimal. Most flights are in summer or early fall so the ground truth can be obtained shortly after the flight.

Photo Interpretation

Photo plots are delineated on 70 mm color infrared transparencies and numbers of dead spruce counted for each plot. A Bausch and Lomb 240 Z stereoscope mounted on a Richards light table greatly aid interpretation since the enlarged film image is at the optional degree of resolution. Each photo plot is located on a resource photograph (1:15,840) and then transferred to a topographic map in order to accurately recompute the photo scale for each plot. Templates are prepared for each scale to cover the desired plot area. Normally, photo plots cover 1 to 3 percent of the total survey area.

3. Ground Truth

The number of photo plots selected for ground examination is based on the total number of photo plots and their size. About 5 percent of the photo plots usually are surveyed on the ground and a two-man crew can survey one 2.5-acre plot each day. Resource photography and a pocket stereoscope help the crews locate these plots and establish plot boundaries. A clinometer and a 100-foot tape accurately measure the ground truth plot boundaries. Plot corners should be staked and string used to delineate the plot boundaries and strips

within the plot. This greatly assists the ground crew locate and count the standing dead trees. Tree mortality is recorded as number of dead trees by species, d.b.h., and cause of death. Tree diameter measurements allow photo plot estimates to be adjusted for trees less than 5 inches d.b.h. Since these trees are most often hidden in the understory by larger dominant trees, they are missed during photo interpretation.

Data Analysis

A linear regression analysis is made using the photo interpretation data and ground truth data from the same plots. The regression equation corrects the photo interpretation estimate of dead trees per acre for each photo plot to improve the mortality estimate for the entire outbreak area. Good linear association (r values at or near the 95 percent confidence level) and high coefficients of determination (r^2 value of 0.9) between photo plot and ground truth plot counts of dead trees can be obtained with minimal training by novice photo interpreters using the equipment and procedures discussed previously (Lessard and Wilson, 1977).

5. Disadvantages of Aerial Surveys

Surveys based on aerial photography have several disadvantages. First, successful missions are dependent on minimal cloud cover. Since timing of the mission is not critical, this disadvantage is negligible for the southern and central Rockies and more of a matter of inconvenience and schedule changing. A more important disadvantage is the yield of data—numbers of dead trees per acre. If the forest manager only needs to know the numbers of dead standing trees, then aerial survey can provide adequate data. If the manager needs to know the height and diameter range and the information is not available from compartment files or Stage II inventory, then aerial surveys are inadequate—ground truth subsamples do not provide enough coverage. Another disadvantage is the accuracy of the estimate from the photos. Aerial photography overestimates the number of dead trees if many trees killed by non-beetle sources are present, and underestimates the number of dead trees if the mortality is in multi-storied stands where understory trees are camouflaged by the dominant trees. The latter two disadvantages tend to balance each other in some instances.

Aerial surveys have always been promoted as an efficient way to obtain mortality data, primarily because they are cheaper and just as accurate as ground surveys. In the past this may have been true because large areas of inaccessible forest existed. Now, however, substantially more acreage is accessible. This accessibility, plus the costs for aircraft use, for subsequent photo interpretation and ground truthing and the yield of data from aerial surveys suggest the need for a detailed benefit-cost evaluation comparing an aerial survey to a ground survey of the same area.

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